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Field Trial and Agronomic Performance of Antibiotics in Naturally-Colored Cotton Against Key Leaf Damaging Pests

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ABSTRACT

Laboratory tests were conducted to acquire the antibiotic effect of white and naturally-colored cotton varieties/lines, AP_2, PM_1 and PM_4 compared to the control, SR60, using fresh leaves fed to the 3rd instar *Helicoverpa armigera* larvae. There were no significant differences found in the developmental times and weights of the bollworm larvae and pupae fed on the leaves of the different cotton varieties/lines except for the percentage of adult abnormalities in $PM_1$and PM_4. The leaf damage by the leafhoppers was undertaken in a greenhouse using adult and nymph leafhoppers released in a screen cage containing one month-old cotton plants of each variety/line grown in pots. After 14 days, the results revealed that AP_2 had the lowest score for hopperburn rating (3.5).

Cotton variety trials in sprayed and unsprayed plots were conducted during 2006 and 2007 at two locations, the Field Crop Research Center at Nakhon Ratchasima and a farmer's field at Thongpapoom, Kanchanaburi. The mean annual number of key pests and the annual yield of each variety/line at each location were compared and the average agronomic performance of each variety/line was HVI analyzed. At Nakhon Ratchasima, leafhoppers were more abundant than aphids and whiteflies in both 2006 and 2007. There was a significant difference in the mean leafhopper numbers for AP_2 and PM_4 between both plots during the two years, while for PM_1 there was a significant difference in 2007 only. Seed weights of SR_{60} and PM_1 differed between the sprayed and unsprayed plots in 2006. At Tongpapoom, Kanchanaburi, both SR_{60} and PM_4 in 2006, and PM_4 again in 2007 had significantly different amounts of leafhopper between the sprayed and unsprayed plots. The yield of SR_{60} in the sprayed plot significantly differed from the unsprayed plots in 2006. Agronomic performance of each cotton fiber found only micronaire range in PM_1 from Thongpapoom and the fiber lengths of SR_{60}, AP_2 and PM_1 grown at Nakhon Ratchasima to be designated as premium. At Tongpapoom, the AP_2 fiber length fell in the base range. The percent lint of AP_2 was the highest at Nakhon Ratchasima, while PM_4 had the lowest value for this parameter at both locations.

Key words: naturally-colored cotton, antibiosis, hopperburn rating

INTRODUCTION

Naturally-colored cotton has been produced for indigenous and commercial use in many countries. Growing organic cotton, including naturally-colored cotton, eliminates the need for heavy chemical application by the optimal use of crop rotation, beneficial insects, extracted plant

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substances, resistant varieties, etc. There are at least one or two key pests in every region that produces cotton. Thailand has relatively few pests, with the cotton leafhopper, *Amrasca biguttula* (Ishida) being particularly devastating at present. The cotton bollworm, *Helcoverpas armigera,* though not a primary pest now, also serious if an outbreak occurs. Currently, other important pests are the cotton aphid (*Aphis gossypii)*, whitefly (*Bemesia tabaci),* plant bug (*Megacoelum biseratense),* cotton thrip *(Thrips palmi)* and pink bollworm (*Pectinophora gossypiella)*. Pests of naturally-colored cotton, which are similar to those of white cotton, have been reported by Hormchan *et al*. (2005).

Each cotton variety has its own unique chemical composition. Gossypol, a major terpenoid aldehyde in the subepidermal gland of cotton varieties, has been proven to be antibiotic to many lepidopterous pests including *Helicoverpa armigera* (Wang *et al*., 1993). Lukefahr *et al*. (1966) demonstrated that larval growth of the cotton bollworm *Heliothis zea,* and the tobacco budworm, *Heliothis virescens* , was related to the content of gossypol in the cotton plant supplied through the pigment glands.

Aphids, leafhoppers, psyllids, whiteflies, scale insects, and other homopterous pests are sensitive to neem products to varying degrees. It has been shown, for example, that low doses keep the green rice leafhopper from infecting rice fields with tungro virus (www.greenstone.org/greenstone3/nzdl;jsessionid=C3ED85058F1CF78F29947A1D172 139C2?a=d&c=hdl&d=HASH0... -). Confidor has been recommended in Pakistan to control sucking insect pests of cotton such as leafhoppers, thrips, whitefly and aphid (http://www.sindhagri.gov.pk/pesticides%20rpt/pest recom/Pesticide% 20Recom%20crop.pdf.) Aslam *et al*. (2004) reported on a field trial which found Confidor, Mospilan and Tarmaron gave the most effective control against leafhoppers up to seven days after spraying.

The laboratory tests in this study were conducted to evaluate the antibiotic effect of chemical compounds on the biological parameters of the bollworm. The damage caused by the cotton leafhopper on the tested cotton lines and a control was also investigated. The aim of the field test was to compare the damages caused by the pests on white and naturally-colored cotton varieties/lines with and without the application of organic insecticides.

MATERIALS AND METHODS

Antibiotic test by feeding assay of the bollworm

Four cotton varieties/lines were used in this study: the naturally-colored lines originally from France - PM_1 brown and PM_4 green, the new line AP_2 and the control - SR_{60} white, the recommended variety. The bollworm larvae were obtained from the Division of Entomology and Zoology, Department of Agriculture. Each genotype was planted in pots kept in the greenhouse. Foliages were collected when the plants had reached their blooming stage. Terminal young leaves were excised and placed into 9.5 cm by 15 cm Petri dishes lined with moistened #1 filter paper. Ten Petri dishes were used per variety/line per replication, with four replicates per variety/line. One 3rd instar bollworm larva was placed on the foliage in each Petri dish. The Petri dishes were incubated under laboratory conditions at 30°C and 70% RH. The filter paper within each Petri dish was kept moist by applying approximately 1 ml of water every other day. After 48 h, the larvae were weighed and reared through to adults with an artificial diet. All data were statistically analyzed.

Leaf damage by the leafhopper (hopperburn rating)

Ten adult and nymph leafhoppers from the lab culture were released in each four-sided

screen cage of 1×1×1 ft in size with one month-old cotton plants of each of the four varieties/lines, SR_{60}, AP_2, PM_1, and PM_4 grown in pots. After seven days, the leafhoppers were taken out and the plants were left to grow. After another seven days, the amount of hopperburn on each cotton variety was rated. The procedure was repeated three times. Hopperburn was rated on a scale of 1 to 7 according to Renou *et al*. (1998) as follows: 0 = no leaf injury ; 1 = beginning of yellowish margins ; 2 = yellowish margins ; 2.5 = beginning of reddening margins ; 3 = spread of yellowing to lamina ; 3.5 = spread of reddening to lamina ; 4 = beginning of drying on margins ; 4.5 = appearance of hopperburn on margins ; 5 = hopperburn on all margins ; 6 = spread of hopperburn to lamina ; 7 = all leaves dried or burnt.

Field test

Cotton variety trials were conducted during 2006 and 2007 at two locations, the Field Crop Research Center at Nakhon Ratchasima and a farmer's field at Thongpapoom, Kanchanaburi. The years largely differed between the amount of rainfalls recorded at each location was considered as an individual environment. Two naturally-colored cotton lines, PM_1 and PM_4, the new line AP_2 and the recommended variety SR_{60} were grown at the Nakhon Ratchasima Field Crop Research Center and the farmer's field at Thongpapoom starting last week of August, 2006 and 2007. There were two experiments involved in the comparison study: Experiment 1 with the application of neem, (1000 cc/20 liter of water), alternated with Confidor (10 cc/20 liter of water) and Experiment 2 without the Confidor. A randomized complete block design (RCB) with four replications was used, with four varieties/line. Rows of 20 meters long were established one meter apart with a plant spaced every one meter along the row, with five rows for each replicate. Four weeks after planting at each location, plants were thinned to one per hole. The crops were partly fed with rain water and partly irrigated. Weed control and fertilizer application were administered as required. Eight weeks after planting, the economic threshold of each key pest, the bollworm and leafhopper, was used to determine if the application of neem and/or the synthesized organic compound was needed in Experiment 1. The number of key insect pests present on two leaves, top and bottom randomly selected from the five plants of the two middle rows in each replication was recorded every other week, starting when the cotton plants were two months old. Yields were harvested and weighed. Comparisons of insect pest numbers and yields, both quantity and quality, for each cotton variety/line were then made. The agronomic performance of the cotton fiber was HVI analyzed by the Textile Testing Center, Thailand Textile Institute.

RESULTS AND DISCUSSION

Antibiotic test by feeding assay of the bollworm

Comparisons of the new line, AP_2, the naturally-colored cotton lines, PM_1 and PM_4, with the control SR_{60} with respect to the biological parameters of the bollworm, *H.armigera*, found no significant differences ($P \leq 0.05$) for the average bollworm larval and pupal weights as well as for the developmental times of the larvae and pupae. The highest percentage of adult emergence and the lowest percentage of abnormal adults were found in PM_1 (Table 1).

Even though no significant differences between the control and tested cotton lines were found for most characteristics, a higher percentage of adult abnormality was observed with PM_1 and PM_4 than with SR_{60}. The different effect might come from the biochemical composition in either the relative amounts or types of the constituent compounds, as stated by Mullin and Pieters (1982) who also tested for an antibiotic result using resistant and susceptible cotton strains fed to the tobacco budworm. These biochemical variations

Table 1 Antibiotic effect of white and naturally-colored cotton variety/line on *H. armigera* larvae by feeding under laboratory conditions.

Var/Line	Mean larval wt[1/] after 48 hrs (g)	Mean larval period[1/] (Days)	Mean pupa wt [1/] (g)	Pupal period[1/] (Days)	Adult emergence (%)	Abnormal adult (%)
SR_{60}	0.0007a	16.6a	0.2932a	11.5a	40	50
AP_2	0.0018a	17.0a	0.3000a	14.0a	50	50
PM_1	0.0008a	17.0a	0.2802a	11.3a	70	30
PM_4	0.0010a	16.3a	0.2054a	11.8a	50	40

[1/] Means followed by the same letters in the same columns are not significantly different at the 95% level as determined by Duncan's multiple range test

may differentially affected the biology of the insects feeding on them. Hormchan and Wongpiyasatid (2006) evaluated antibiotic effects by fresh leaf/square feeding of new cotton lines to *H.armigera* larvae and found a significant difference between the larval period of one tested line and the control. A direct comparison with the results of this study could not be made because a different cotton varieties/lines were used. However, in both experiments, the effects on the bollworm larvae were caused by an antibiosis mechanism.

Leaf damage test of leafhopper (hopperburn rating)

A comparison was made among the four cotton varieties (AP_2, PM_1, PM_4 and the white recommended variety, SR_{60}) in order to investigate the relative resistance to leafhopper damage under greenhouse conditions (Table 2). PM_1 and the control SR_{60} showed the highest severity of hopperburn symptoms, followed by PM_4. The least severe symptoms were found in AP_2. A hopperburn index (a leafhopper resistance index) proposed by Nageswara Rao (1973) grouped an injury index into four resistant categories. Based on such an index, AP_2 would be placed in the moderate resistance category, while the other varieties would be placed in susceptible categories. In a field experiment, Hormchan *et al*. (2001) found that the tested cotton lines showed a trend from moderate resistance to the cotton leafhopper when they were young and became more susceptible as they grew older.

Table 2 Hopperburn rating of white and naturally-colored cotton varieties/lines under greenhouse conditions.

Variety/Line	Hopperburn rating
SR_{60}	6.0
AP_2	3.5
PM_1	6.0
PM_4	5.0

Field test

Over a two-year period from 2006 to 2007, a comparison between sprayed and unsprayed plots was made on the amount of insect pest attacking on cotton plants of each variety/line at the Nakhon Ratchasima Field Crop Research Center and at Tongpapoom, Kanchanaburi. Three key pests were recorded: cotton leafhopper, cotton aphid and whitefly, with the leafhopper the most common. An economic threshold of leafhopper damage (Khaing *et al*., 2002) was employed before any application of natural/synthetic insecticide was undertaken. At the Nakhon Ratchasima Field Crop Research Center, a significant difference between the sprayed and unsprayed plots was found in the mean leafhopper numbers on AP_2 and PM_4 during both years, while for that of PM_1 the difference was significant in 2007 only (Table 3). No significant differences between the sprayed and unsprayed plots were

observed in either mean aphid or whitefly numbers with any variety/line (Tables 4 and 5) over the two years. Significantly-higher seed weights for SR_{60} and PM_1 were observed in the sprayed plots compared to the unsprayed plots in 2006 (Table 6).

Although the three key pests were observed during both years in the sprayed and unsprayed plots at the Nakhon Ratchasima Field Crop Research Center, only the leafhoppers were abundant. In 2006, all cotton varieties/lines were able to grow well with yields higher than those grown in 2007. This might be due to the lower rainfall (3.06 mm) in 2006, compared to 2007 (5.07 mm) during the late rainy season (meteorological data provided by Nakhon Ratchasima Field Crop Research Center). The excess rain water caused flooding in the plots and drowned the roots, resulting in stunted growth of the cotton plants.

In both years, applying a neem alternate with Confidor when damage reached economic

Table 3 Mean number of leafhoppers/plant for white and naturally-colored cotton varieties/lines in the sprayed and unsprayed plots in 2006 and 2007 at the Nakhon Ratchasima Field Crop Research Center, Nakhon Ratchasima.

Var/Line	2006		t value	2007		t value
	Sprayed	Unsprayed		Sprayed	Unsprayed	
SR_{60}	26.7	36.4	0.467	1.8	9.0	2.13
AP_2	5.6	23.1*	2.910	1.7	5.8*	2.57
PM_1	27.8	43.8	0.768	7.6	26.5*	2.66
PM_4	11.9	38.5*	3.360	6.1	19.3*	3.48

* Differences between mean number of leafhoppers/ plant statistically significant at the 95% level

Table 4 Mean numbers of aphids/plant for white and naturally-colored cotton variety/line in the sprayed and unsprayed plots in 2006 and 2007 at the Nakhon Ratchasima Agronomy Research Center, Nakhon Ratchasima.

Var/Line	2006[1/]		t value	2007[1/]		t value
	Sprayed	Unsprayed		Sprayed	Unsprayed	
SR_{60}	1.8	2.3	0.144	0.7	6.3	1.030
AP_2	2.3	6.5	0.668	0.8	2.4	1.570
PM_1	3.0	6.0	0.469	0.3	0.5	0.447
PM_4	1.2	4.6	1.210	0.7	0.5	0.156

[1/] Differences between mean number of aphids/plant not statistically significant at the 95% level

Table 5 Mean numbers of whiteflies/plant for each white and naturally-colored cotton variety/line in the sprayed and unsprayed plots in 2006 and 2007 at Nakhon Ratchasima Field Crop Research Center, Nakhon Ratchasima.

Var/Line	2006[1/]		T value	2007[1/]		t value
	Sprayed	Unsprayed		Sprayed	Unsprayed	
SR_{60}	0.4	0.7	0.351	0.8	1.1	0.186
AP_2	1.4	2.5	1.520	0.9	0.5	0.676
PM_1	0.4	1.9	1.330	1.3	0.9	0.585
PM_4	2.1	3.4	1.140	1.0	1.3	0.264

[1/] Differences between mean number of whiteflies/ plant not statistically significant at the 95% level

Table 6 Mean seed weight/16 plants (g) for each white and naturally-colored cotton variety/line from the sprayed and unsprayed plots in 2006 and 2007 at Nakhon Ratchasima Field Crop Research Center, Nakhon Ratchasima.

Var/Line	2006		t value	2007		t value
	Sprayed	Unsprayed		Sprayed	Unsprayed	
SR_{60}	3762.0	649.7*	4.72	549.8	211.7	2.070
AP_2	4360.5	2293.7	1.05	310.1	307.0	0.445
PM_1	3033.2	1227.4*	3.13	655.1	460.8	0.550
PM_4	2556.7	1354.7	2.12	209.0	189.7	0.046

* Differences between seed weight/16 plants statistically significant at the 95% level

threshold for leafhoppers, controlled damage to AP_2, but did not increase yield. In fact, for AP_2, yields in the sprayed plots were not significantly different from the yields in the unsprayed plots. This suggested that the damage due to leafhoppers in the unsprayed plots, did not reduce yield. In other words AP_2 was moderately resistant to the leafhoppers according to the greenhouse test on hopperburn rating. Compared to the control SR_{60} with hopperburn rating of 6, AP_2 and PM_4 were more resistant to leafhoppers with ratings of 3.5 and 5 respectively, while PM_1 had the same rating as SR_{60} (Table 2) . Significant differences between yields in the sprayed and unsprayed plots of SR_{60} and PM_1 also indicated that the reduced yield in the unsprayed plots was caused by the loss of leaves due to leafhoppers. This could confirm that both these varieties/lines were susceptible to leafhoppers.

The result for AP_2 and SR_{60} was in contrast to the findings reported by Sanford and Webb (1977) who studied the loss of yield resulting from an infestation of potato leafhoppers in potato selections. Significant differences were found between the levels of infestation and in the percent of hopperburn among the selections, but even those selections with the most resistant foliage greatly reduced yields when infested. No selections were found that consistently produced a normal yield when infested with leafhoppers. As Braun (1997) stated, the cotton leaves were not as greatly affected as the bolls in the late growing season. Because leaves were more important for potato than for cotton in determining the final yield, the results were different in the two crops. Leafhoppers, unlike the other pests, are found both in the early and late growing season, causing most damage to leaves, not the bolls.

Similar experiments to those in the Nakhon Ratchasima Field Crop Research Center were conducted in the farmer's field at Tongpapoom, Kanchanaburi and the results were analyzed using the same procedures as described above. Significantly higher numbers of leafhoppers of SR_{60} and PM_4 in 2006 and of PM_4 in 2007 were encountered in the sprayed plots compared to the unsprayed plots (Table 7). There were no significant differences between the two plots in mean aphid numbers for all varieties/lines in both years (Table 8), while the mean number of PM_4 whiteflies was found to be significantly different in 2006 (Table 9). In 2006, Table 10 shows the mean seed weight of SR_{60} in the sprayed plots to be significantly different from the unsprayed plots.

The results obtained by examining the yield data generally differed from the insect data, as they showed some statistically-significant interactions between treatment factors. Seed yield was comparable between the unsprayed plots of AP_2 and the control SR_{60} when the number of leafhoppers was abundant. However, when leafhopper numbers were reduced by the application of insecticide, varieties generally produced more seed than their counterparts did. The influence of other factors affecting yield, such

Table 7 Mean numbers of leafhopper/plant for each white and naturally-colored cotton variety/line in the sprayed and unsprayed plots in 2006 and 2007 at Tongpapoom, Kanchanaburi.

Var/Line	2006		t value	2007		t value
	Sprayed	Unsprayed		Sprayed	Unsprayed	
SR_{60}	2.06	7.44*	4.02	2.8	3.8	0.610
AP_2	1.44	3.61	1.90	2.3	3.1	0.657
PM_1	2.44	6.38	1.93	6.8	5.3	0.723
PM_4	2.19	7.31*	3.46	3.5	4.9*	2.920

* Differences between mean number of leafhoppers/plant statistically significant at the 95% level

Table 8 Mean numbers of aphid/8 plants for each white and naturally-colored cotton variety/line in the sprayed and unsprayed plots in 2006 and 2007 at Tongpapoom, Kanchanaburi.

Var/Line	2006[1/]		t value	2007[1/]		t value
	Sprayed	Unsprayed		Sprayed	Unsprayed	
SR_{60}	0.417	1.33	1.010	8.9	16.2	0.690
AP_2	0.917	1.25	0.285	6.4	7.7	0.290
PM_1	0.060	1.83	1.240	1.9	3.3	0.498
PM_4	0.167	2.17	1.020	3.0	11.4	1.300

[1/] Differences between mean number of leafhoppers/plant not statistically significant at the 95% level

Table 9 Mean numbers of whiteflies/8 plants for each white and naturally-colored cotton variety/line in the sprayed and unsprayed plots in 2006 and 2007 at Tongpapoom, Kanchanaburi.

Var/Line	2006		t value	2007		t value
	Sprayed	Unsprayed		Sprayed	Unsprayed	
SR_{60}	0.80	2.38	1.700	2.7	2.8	0.452
AP_2	1.05	1.81	0.913	1.2	2.9	1.440
PM_1	2.00	1.19	2.360	1.7	1.7	0
PM_4	1.62	3.56*	3.080	2.9	1.8	0.316

* Differences between mean number of leafhoppers/plant statistically significant at the 95% level

Table 10 Mean numbers of seed weight/8 plants (g) of each white and naturally-colored cotton variety/line from the sprayed and unsprayed plots in 2006 and 2007 at Tongpapoom, Kanchanaburi.

Var/Line	2006		t value	2007		t value
	Sprayed	Unsprayed		Sprayed	Unsprayed	
SR_{60}	1177.8	512.0*	4.380	728.1	393.9	1.670
AP_2	734.9	546.2	0.443	613.4	500.1	0.739
PM_1	886.6	456.0	0.689	447.0	279.7	1.940
PM_4	690.7	332.9	0.338	366.8	356.9	0.168

* Differences between number of seed weights/16 plant statistically significant at the 95% level

as water relations, could explain the different patterns observed in the yield data versus insect data.

It was observed that PM_4 attracted more leafhoppers than any other variety/line and this was evident in the difference between the sprayed and unsprayed plots in both locations in both years. This result might be influenced by the morphological characters of PM_4, rather than by environmental factors, since the latter were

considered to be similar at the two locations. It was concluded that this aspect required further investigation.

Table 11 presents some agronomic performance and fiber data for the naturally-colored and white cotton from HVI analysis at the Textile Testing Center of the Thailand Textile Institute. It was found that the only premium range micronaire was from PM_1 from Thongpapoom, while SR_{60} from Thongpapoom was in the base range. The remaining samples were classed in the discount range according to Raghavendra et al. (2004). However, according to the U.S. Cotton Fiber Chart, the practical micronaire range for U.S. Upland cotton is 2.0 – 6.0 and so AP_2 would also fall in the same acceptable range. Micronaire values of Fox Fiber cottons were around 2.5-3 for green and 3-4 for brown (http://www.spinnyspinny.com/articles/coloredcotton.html). Although the results could not be properly compared because of different growing time and location, Fox (1987) could still provide an indication of what the micronaire ranges of colored cotton should be and this experiment yielded brown PM_1 and green PM_4 with closely similar values. The report stated that a premium quality of fiber was recognized as coming from environmentally and culturally sensitive production techniques by minimizing or eliminating the use of pesticides and fertilizers while exclusively utilizing hand-harvesting methods (Vreeland, 1996). High micronaire cotton occurs whenever there is an ample or over-abundant supply of carbohydrates. This can be caused by poor boll set with very few bolls on the plant. But the main factor that determines the micronaire value is the environment.

The fiber lengths of SR_{60}, AP_2 and PM_1 grown at Nakhon Ratchasima were designated as premium and PM_4 as discount. At Tongpapoom, only the AP_2 fiber length fell in the base range while the rest were in the discount range. Vreeland (1996) reported fiber length for the colored-cotton perennial tree form to range from 0.48-1.69 inch. Compared to such lengths, the brown PM_1 and the green PM_4 were within the normal ranges for naturally colored cotton.

Lint percentages of AP_2-grown cotton were found to be the highest while PM_4 had the lowest at the two locations. PM_1 had lint percentages relatively close to those of the recommended white SR_{60}. Higher lint fractions in the last 30 years appear to occurr primarily due to smaller seed size rather than an increase in the weight of fibers per seed (Green and Gulp, 1990). Increasing lint per seed may also have implications for ameliorating environmentally-induced variation in fiber properties (Lewis, 1999), by reducing the time necessary to set the crop. Based on field evaluation and fiber analysis, PM_1, the brown variety, appeared to have potential to be recommended for the extension of colored natarally cotton growing.

Table 11 Mean fiber properties of the naturally-colored and white cotton varieties/lines grown at the two locations in 2006 and 2007.

	Nakhon Ratchasima			Thongpapoom		
	Fiber length[1/] (inch)	Micronaire[2/]	Lint (%)	Fiber length (inch)	Micronaire	Lint (%)
AP_2	1.18	5.24	49.7	1.06	5.38	40.0
SR_{60}	1.14	5.05	39.9	1.02	4.84	34.6
PM_1	1.10	4.44	38.4	0.97	3.78	35.3
PM_4	0.94	2.65	30.1	0.87	2.81	34.5

1/ Fiber length: > 1.0938 = premium; 1.0625 = base range ; <1.0625 = discount range

2/ Micronaire: 3.7- 4.2 = premium; 4.3-4.9 = base range ; > 5 = discount range

CONCLUSION

All tested cotton lines, both white and naturally-colored, when compared to the control, SR_{60}, had similar weights and developmental times except for the percent adult abnormality in PM_1 and PM_4, based on the antibiotic-effect test. AP_2 scored a moderate resistance in the hopperburn ratings. At Nakhon Ratchasima, AP_2 and PM_4 , in 2006 and PM_1 in 2007 had significant differences between mean leafhopper numbers in the sprayed and unsprayed plots. Yields of SR_{60} and PM_1 in the sprayed plots differed to those in the unsprayed plots in 2006. At Tongpapoom, significantly different amounts of leafhopper between the sprayed and unsprayed plots were recorded for SR_{60} and PM_4 in 2006 and for PM_4 in 2007. The yield of SR_{60} in the sprayed plots differed significantly from the unsprayed plots in 2006. With the exception of micronaire in PM_1 from Thongpapoom and fiber length in SR_{60}, AP_2 and PM_1 from Nakhon Ratchasima, which were all in the premium range, the remaining samples were all designated as in the discount range. The percent lint of AP_2 at Nakhon Ratchasima was the highest.

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LITERATURE CITED

Aslam, M., M. Razaq, S.A. Shah and F. Ahmad. 2004. Comparative efficacy of different insecticides against sucking pests of cotton**. J. of Res. (Sci.)**. 15(1): 53-58.

Braun, M . 1997. **IPM in Cassava, Cereals,and Cotton, Enhancement of Beneficials and Use of Botanicals.** IPM Training Manual. Tanzanian-German IPM Project, GTZ, PPD, Shinyanga, Tanzania. www.oisatorg/crops/staple_food/cassava.html

Fox, S. 1987. Naturally colored cotton. **Spinoff.** 29: 37.

Green, C.C. and T.W. Gulp. 1990. Simultaneous improvement of yield, fiber quality, and yarn strength in upland cotton. **Crop Sci.** 30:66-69.

Hormchan, P., A. Wongpiyasatid and S. Piyapuntawanon. 2001. Observation of gamma irradiated cotton population on trend of cotton leafhopper resistance using hopperburn index. **Kasetsart J. (Nat. Sci.)** 35: 386-391.

Hormchan, P., A. Wongpiyasatid and S. Piyapuntawanon. 2005. Feasibility study on insect pests affecting the growing of naturally colored cotton comparing with white cotton in Thailand. **Kasetsart J. (Nat. Sci.)** 39: 594-600.

Hormchan, P. and A. Wongpiyasatid. 2006. Evaluation for antibiosis resistance in cotton to *Helicoverpa armigera* Larvae. **Kasetsart J. (Nat. Sci.)** 40: 33-38.

Humanity Development Library 2.0. For sustainable development and basic needs. Effects on Insects.http://www.greenstone.org/greenstone3/nzdl;jsessionid=C3ED85058F1CF78F29947A1D172139C2?a=d&c=hdl&d=HASH0...– July,2008.

Khaing, O., P. Hormchan, S. Jamornmarn, N. Rattanadilok and A. Wongpiyasatid. 2002. Spatial distribution pattern of cotton leafhopper, *Amrasca biguttula* (Ishida) (Homoptera Cicadellidae). **Kasetsart J. (Nat. Sci.)** 36: 11-17.

Lewis, H.L. 1999. How should cotton fiber be improved. 8 p. *In* **Proc. 12 th Annual Engineered Fiber SelectionÆ** System Conf., 18-19 May, 1999. www.cottoninc.com/1999ConferencePresentations/HowShouldFiberQualityBeImproved/.

Lukefahr, M.J., L.W. Noble and J.E. Houghtaling. 1966. Growth and infestation of bollworm and other insects onglanded and glandless

strains of cotton. **J. Econ. Entomol.** 59: 817-820.

Mullins, W. and E.P. Pieters. 1982. Effect of resistant and susceptible cotton strains on larval size, developmental time and survivalof the tobacco budworm. Entomolo. **Soc. of Amer.** 11(2): 363-366.

Nageswara Rao, P. 1973. An index for jassid resistance in cotton. **Madras Agri. J.** 60: 264-266.

Naturally Colored Cotton. http//www.spinnyspinny.com./articles/coloredcotton.html

Pesticide Recommendation for Field Crop: Cotton Insect Control. http://www.sindhagri.gov.pk/pesticides%20 rpt/pestrecom/Pesticide%20Recom%20crop. pdf.

Raghavendra, R., A.D. Hedge, M.G. Kamath, Xio Gao and Praveen Kumar Jangala. 2004. Cotton fiber. http://www.engr.utk.edu/mse/Pages/Textiles/Cotton%20fibers.htm

Renou, A., W. Eittipibool and B. Kideng. 1998. Annual report 1997/1998. **Entomological Research. Development Oriented Research on Agarian Systems Center.** Kasetsart University. 95p.

Sanford, L.L. and R.E. Webb. 1977. Loss of yield in potato selections infested with potato leafhoppers. **American Journal of Potato Research.** 54(12): 581-586.

Vreeland, J.M. 1996. Organic and naturally colored native cotton from Peru, South America, Bremer, pp 129-140. *In* H. Hang and S. Heap (eds.). **Proceedings,Bremer, baumwolborse, 23rd International Cotton Conference**, Faserininstitut.

Wang, C.Z., Q.W. Zhang, Q.H. Yang and M.Z. Zhou. 1993. Gossypol hydrolysable tannin in cotton contributing to resistance to the cotton bollworm, *Helicoverpa armigera* (Hubner). **Acta Agriculture Universitatis Pekinensis.** 19 (Suppl): 66-70.